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Quantification in starch microstructure as a function of baking time

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Abstract

The purpose of this study was the characterization of micro structural and thermal aspects of starch gelatinization in wheat dough/crumb during bread baking. The microstructure of starch granules was examined by *confocal-laser-scanning-microscopy (CLSM)* and evaluated by an image analyzing tool. Supporting crystallinity changes in wheat dough/crumb were analyzed by *differential-scanning-calorimetry (DSC)* and calculated by the content of *terminal extent of starch gelatinization (TEG)*. The micrograph of processed *CLSM* data showed starch structure changes during baking time. After gelatinization the starch fraction itself was inhomogeneous and consisted of swollen and interconnected starch granules. Image processing analyses showed an increment of mean granule area and perimeter of the starch granules. The results of *DSC* were examined to present an equation which provides a mean of predicting *TEG* values as a function of baking time. *CLSM* and *DSC* measurements present high significant linear correlation between mean starch granule area and *TEG* ($r = 0.85$). The possibility to combine *CLSM* with thermal physical analytical techniques like *DSC* in the same experiments is useful to obtain detailed structural information of complex food systems like wheat bread. Finally, it offers the option to enlarge the knowledge of microstructural starch changes during baking in combination with physicochemical transformation of starch components.

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Keywords: bread crumb; starch gelatinization; CLSM; DSC.

1. Introduction

The change from dough to bread during thermal heating process entails important structural modifications which depend on specified process conditions [1-5]. The resting time - used for dough rise and structure relaxing – is followed by the baking process which is an irreversible process causing physical and chemical changes of the product components with the objective of a specified volume and stabilized crumb structure. The volume depends on the oven-rise which is driven by the gas expansion.

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These gases, mainly - air, EtOH, CO_2 and water vapour, contribute to the bubble inflation during baking [6]. After the oven-rise, whilst thermal heating, protein denaturizes, starch gelatinizes and the crust formation creates a stabilized product.

Starch is the main component of wheat bread and its gelatinization induces major structural changes during baking. The knowledge about the degree of gelatinization is an important factor for the control and optimization of thermal heating processes. This gelatinization process involves partly irreversible structural changes of the starch granules with concurrent loss of its molecular order or crystallinity [7]. The swollen granules and partially solubilized starch act as essential structural elements of bread.

Various analytical methods have been used to describe starch gelatinization, e.g. ultrasonic, viscometers, *enzymatic analysis (EA)*, *nuclear magnetic resonance (NMR)*, X-ray crystallography, thermal- *(DSC)* and microscopic-analysis like *electron microscopy (EM)* and *light microscopy (LM)* [8-10]. Especially *LM* presents a valuable method for the study of the microstructure changes in starch [11-14]. Several authors [12, 15] have pointed out the difficulty involved in preparing dough and bread samples for microscopy. The disruption of the protein network and a distorted image of the bread crumb due to hydration during fixation [12] and staining are procedural methods. The shrinkage of starch and protein as a consequence of dehydration is also described. To validate these problems the *confocal laser scanning microscopy (CLSM),* which is a technique for obtaining high resolution optical images with depth selectivity, was used by some authors [16-17]. The main advantage of *CLSM* is the ability to acquire in-focus images from selected depths without sample destruction. *CLSM* is already an approved method to visualize starch gelatinization. Primo-Martín et al. [18] e.g. used the confocal laser technique compared with *LM* to visualize the starch crystallinity in bread crust.

Besides these microscopic methods, the *differential scanning calorimetry (DSC)* - in which the thermal energy is required for maintaining a given rate of temperature changes - was used as one of the main tools for the investigation of thermally induced starch gelatinization during the course of the baking process [19]. Several parameters can be defined by *DSC:* gelatinization temperature (T_{max}, corresponding to that where half of the granules have lost their birefringence), initial or onset temperature (T_{on}, where birefringence loss starts) and final or end temperature (T_{end}, where 90 % of the granules have lost their birefringence) [20]. These temperatures, especially the gelatinization temperature, are characteristic of the biological origin of starch and a reflection of its internal structure.

Up to now all microscopic methods are restricted methods because they only focus on a group of objective of the structural changes. The usage of an image analyzing system is a crucial factor for the quantification of the results. The microstructure of starch granules was examined by *confocal laser scanning microscope (CLSM)* and analyzed by an image processing tool. Supporting crystallinity changes in wheat dough/bread were analyzed by *differential scanning calorimetry (DSC)* and calculated by the *terminal extent of starch gelatinization (TEG)*. The aim of this study was to characterize the micro and thermal structure of starch gelatinization in wheat dough/crumb during baking and to combine both analyzing systems to enhance their explanatory power.

2. Materials and Methods

2.1. Ingredients

All ingredients were weighed and mixed first under slow for 1 min at 53 rpm followed by faster mixing for 6 min at 106 rpm (Diosna laboratory kneaders with group controller, Multimixing S.A. GmbH, Osnabrück). An optimum of the dough temperature of 28 °C was maintained by tempering with the used distilled water. After mixing the dough was rested for 20 min at 30 °C and a relative moisture of 80 % (KOMA Koeltechnische Industrie, Roermond, Niederlande). Subsequently breads of 150 g were weighted, formed and placed in a tin (conical 110x70x80 mm, bottom 100x60 mm) (BICO GmbH,